MODIS Semi-Annual Report, June 2000
Y. Kaufman, D. Tanre, L. Remer,
A. Chu, V. Martins, S. Mattoo, R. -R. Li, C. Ichoku, R. Levy, R. Kleidman

This reports covers the **aerosol ocean** and **aerosol land** algorithm, and our involvement in the **NIR water vapor**, **cirrus** and the **fire** algorithms. It is the first to cover actual use of the MODIS data.

Main topics addressed in this period:

AEROSOL OVER LAND AND OCEAN

1. Analysis of MODIS aerosol products in various aerosol events (air pollution, smoke, and dust) (*Chu, Mattoo, Levy*)
2. Validation of MODIS aerosol optical depths with AERONET ground observations (*Kaufman, Tanre, Remer, Chu, Mattoo*)

ALGORITHM ENHANCEMENT & DEVELOPMENT

5. Delivery of MODIS PGE04 version 2.5.0 algorithms including aerosol (over land and ocean), water vapor, and water vapor correction. (*Chu, Mattoo)*
6. Development, test, and implementation of 3 x 3 cloud screening using 0.55 µm spatial variance over ocean (*Martins, Mattoo*)
7. Implementation of 3 x 3 cloud screening using 0.47 and 1.38 µm spatial variance over land (*Chu, Martins*)
8. Implementation of change of percentiles in selecting dark pixels (*Chu, Kaufman*)

OTHER TOPICS

9. The PRIDE experiment (*Remer, Levy, Kleidman*)
10. Software development of deriving statistics from MODIS and AERONET aerosol properties (*Ichoku, Kaufman, Remer, Chu*)
11. Development of aerosol transport model (*Kaufman*, *Dubovik*, Lapyonok)
12. Calibration of ASD spectrometer and Microtops sunphotometer (*Levy, Ichoku*)
13. Study of sub-pixel snow/ice detection using 0.66 and 2.1 µm channels (*Kleidman, Kaufman*)
14. Revision of MODIS Atmosphere QA Plan. (*Chu*)
15. Application of the MODIS aerosol, water vapor, and cloud mask algorithms to all SCAR-B and TARFOX MAS data. (*Li, Remer*, *Kaufman*)
16. Trajectory analysis of using NCEP wind data for aerosol transport study in Egypt Africa. (*Ichoku, Li*, *Remer, Kaufman)*
17. Analysis of the SeaWifs measurements during EOPACE-Duck Field Experiment. (*Levy, Kaufman, Remer*)

18. Paper acceptance/submission/preparation. (*Kaufman, Remer, Kleidman, Ichoku, Chu, Levy*)
19. Meeting & workshop. (*Kaufman, Remer, Chu, Mattoo, Li, Kleidman, levy, Ichoku*)


1. Analysis of MODIS aerosol retrievals in various aerosol events (air pollution, smoke, and dust)

A number of aerosol events including African and Asian dust outbreak, biomass burning in Central America and Europe, and air pollution in Northern America are chosen for detailed analysis including cloud screening, surface identification (vegetation, soil, water, shadow, snow/ice, and glint), and selection of aerosol models. Shown below are a few examples of retrieved aerosol optical depths over land and ocean.
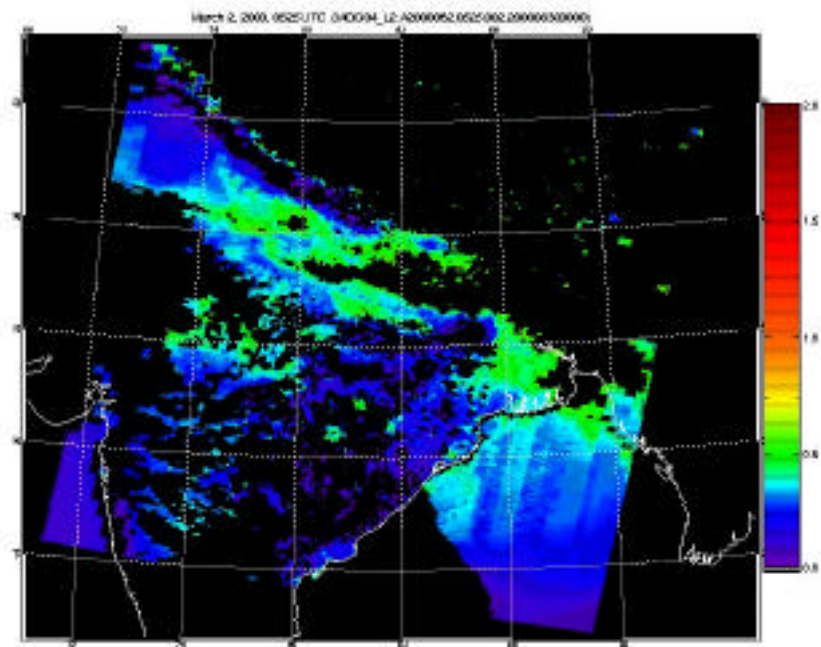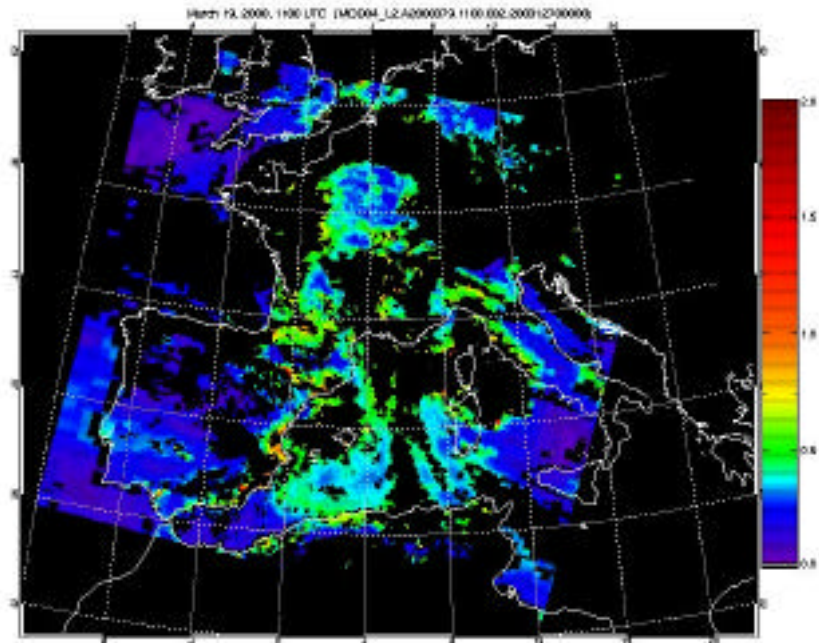
• *Africa Dust & Smoke (March 11, 2000)*
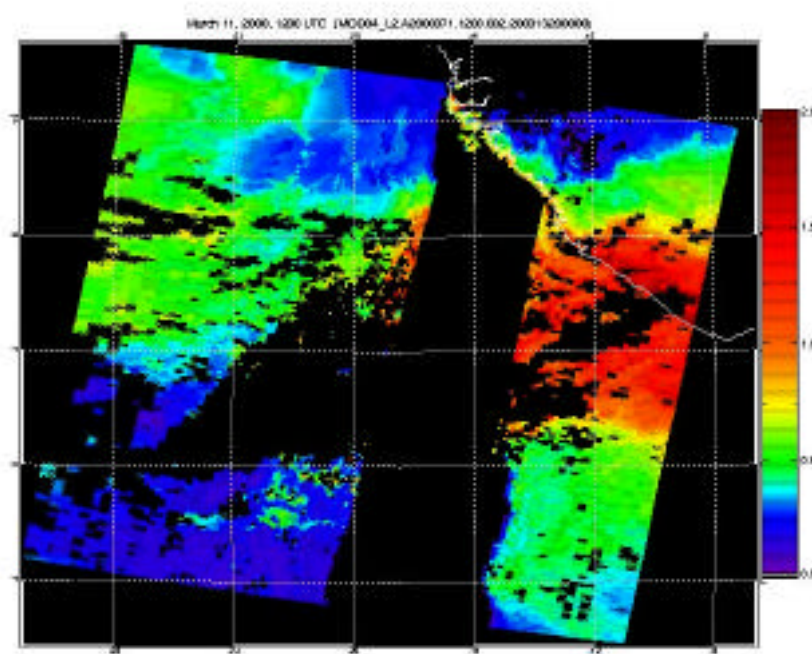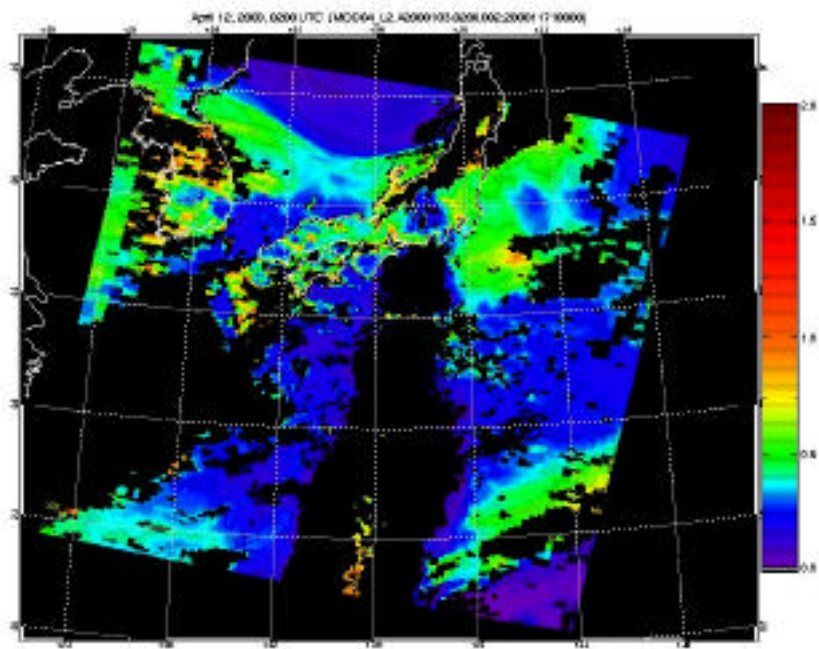

• *Central America Smoke (April 19,2000)*
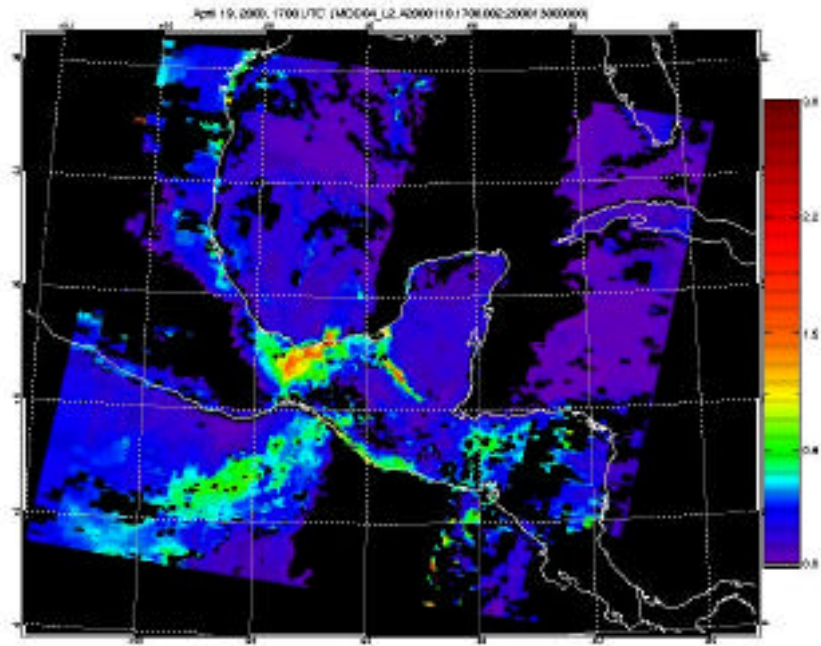
• *India Pollution (March 2, 2000)*


• ***Europe*** *Pollution (March 19, 2000)*

• *China Dust and Pollution (April 12, 2000)*

The problems encountered in aerosol retrievals are primarily due to the contamination of clouds (especially cloud edge and broken clouds), snow/ice, sun glint, uncertainty of land surface reflectance, and aerosol models.

2. Validation of MODIS aerosol optical depths with AERONET ground observations

The primary criteria for validating aerosol optical depth are based upon AERONET sunphotometer measurements. The comparisons of MODIS-retrieved aerosol optical depths and AERONET direct-sun aerosol optical depth measurements are shown below respectively over land and ocean. Other validation criteria include land-sea contract, view angle dependence, aerosol model selection, particle size, and wind pattern in aerosol transport. Detailed validation in regard to aerosol types should be performed to evaluate the validity of aerosol models.
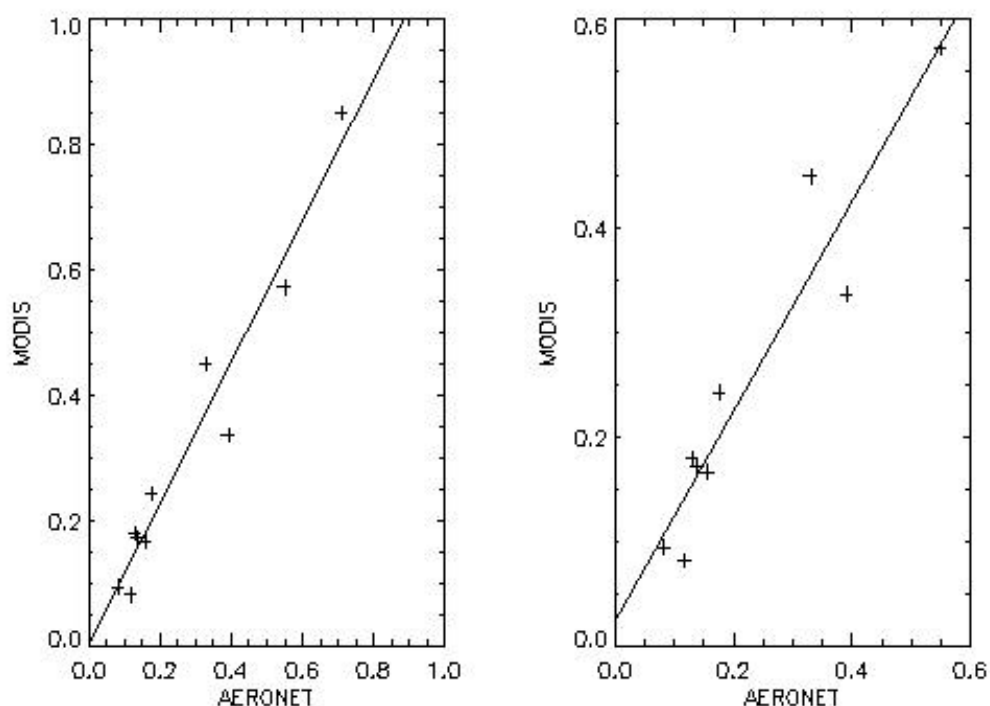
Comparisons of MODIS-derived aerosol optical depths and AERONET direct-sun measurements over land. At 0.47 and 0.66 µm channels at left and right respectively
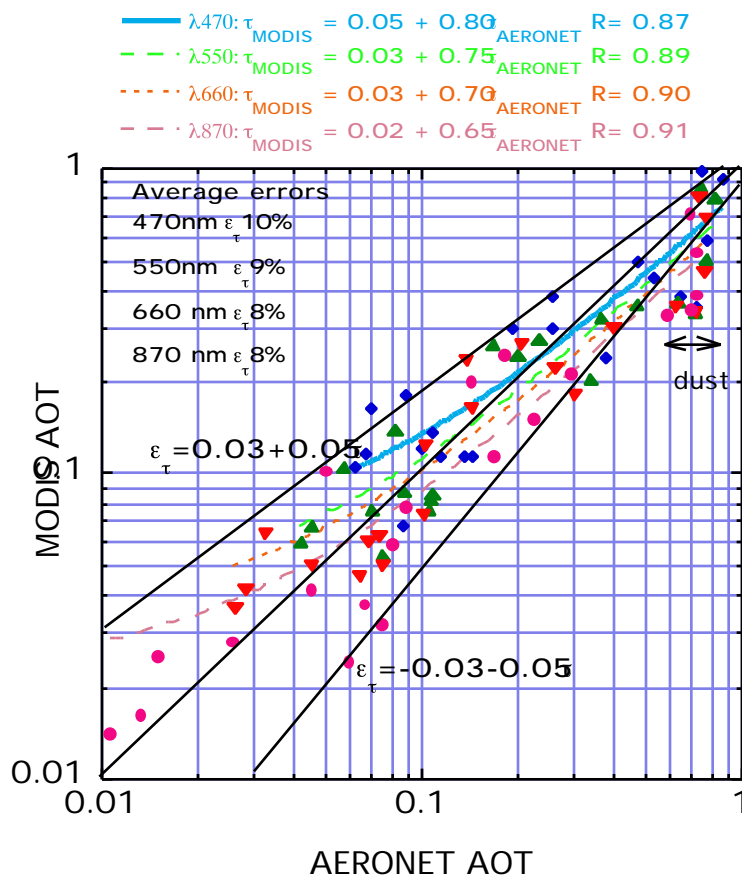
Validation of the ocean algorithm over the ocean in four spectral channels 0.47-0.87 μm. The black lines are the errors anticipated based on the Tanre et al. 1999 paper. Note that except for the validation for dust there is a very good agreement between the data. Newer results are though less optimistic. The dust validation is discussed in the next figure.
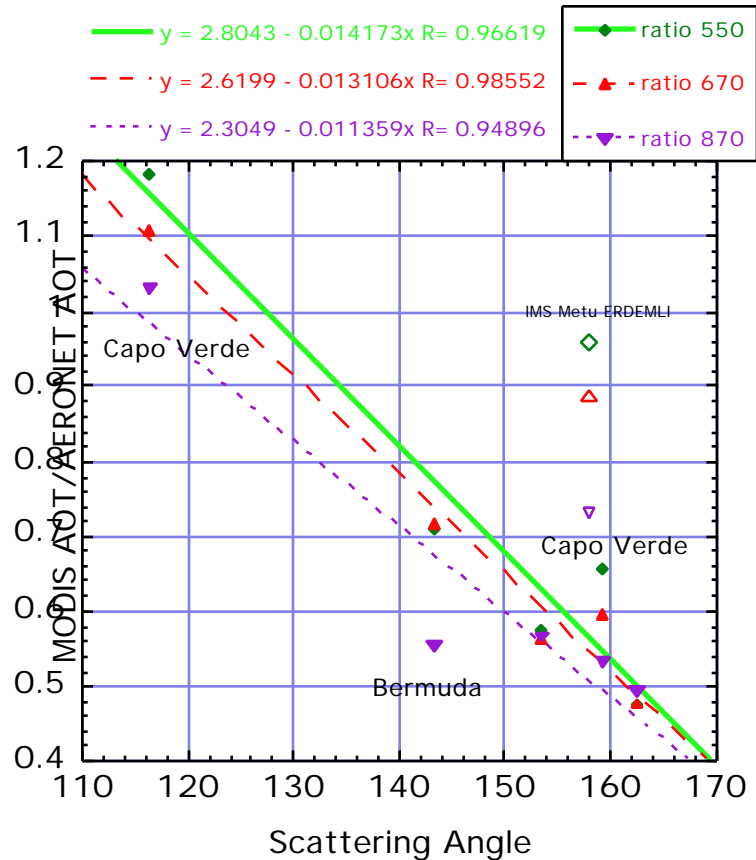
This figure demonstartes evaluation of the MODIS ocean algorithm over the ocean. The ratio of the MODIS measurements in Capo Verde to that of AERONET is plotted as a function of the scating angle. It is anticipate that the nonspherical nature of dust will introduce systematic errors as a function of the scattering angle. While for scattering angles of 120 degrees, as predicted by Tanre et al (2000 submitted), there is no significant effect of the nonsphericity and the results of AERONET agree with those of MODIS, for scattering angles of 160 there is a difference of 40%. We need more data to evaluate this issue.

5. Delivery of MODIS PGE04 version 2.5.0 algorithms including aerosol (over land and ocean), water vapor, and water vapor correction

The new PGE04 (version 2.5.0) algorithms of aerosol, water vapor and water vapor correction were delivered and integrated into MODIS production system on July 17, 2000. In addition to bug fixes, the enhancement of using 3 x 3 pixels clouds screening based upon spatial variance is implemented for aerosol retrieval over ocean. The selection of valid pixels is also changed to take into account bad pixels in order to increase the retrievals. Production rules of using NCEP ancillary data are changed to accommodate data availability. Other changes were made in the water vapor correction. These algorithms are

thoroughly checked for bounds, floating-point exception, and array indices. Next delivery will include enhancements for aerosol retrieval over land, such as adjacency effect, cloud screening, percentile in selecting dark targets, and derivation of aerosol path radiance.

6. Development and implementation of 3 x 3 cloud screening using 0.55 μm spatial variance over ocean

The University of Wisconsin cloud mask was designed to locate unobstructed views of the surface of the earth. However, the cloud mask does not distinguish clouds or heavy aerosol in the viewing direction. In both cases, it defines as a "cloudy" pixel, which prevents retrieving heavy dusts. An alternate cloud mask was developed based on spatial variance as opposed to spectral thresholds. The new technique was tested and performed extremely well even for very heavy dust events and has subsequently been implemented into the algorithm. However, the spatial cohesion cloud mask does miss some smooth high cirrus in some scenes. Four IR tests using University of Wisconsin cloud mask are used to supplement the removal of high cirrus clouds.

7. Test of 3 x 3 cloud screening using 0.47 and 1.38 μm spatial variance over land

The application of spatial variance using visible channel is found to be more difficult over land than over ocean because of larger and more variable surface reflectance. At shorter wavelength, the surface reflectance is smaller, which is the reason to use 0.47 instead of 0.55μm wavelength. The 1.38 μm channel is used to detect high cirrus clouds. The preliminary test shows promising results. Intensive tests are needed in order to apply to all possible conditions.

8. Change in percentiles in selecting dark pixels

In one of the scenarios, where land surface was covered by a thin layer of water, the retrieval consistently overestimates aerosol optical depth. It is most likely due to sub-pixel water bodies. The original 10-40 percentile in selecting dark pixels does not consider sub water pixels. New 70-70 percentiles are proposed by taking into account the surface variation (2.1 μm).

9. The PRIDE experiment

The Puerto RIcan Dust Experiment (PRIDE) observed Saharan mineral dust aerosol above the waters surrounding Puerto Rico, June 26 to July 24, 2000, with the intention of determining the physical, chemical and radiative properties of the dust, the transport processes involved, and the effectiveness of satellite retrievals of dust characteristics in this region. The experiment was led by Dr. Jeffrey Reid of the U.S. Navy's SPAWAR

center, and Dr. Ronald Ferek of the Office of Naval Research. It involved a collaboration of researchers from the Navy, NASA/Goddard, NASA/Ames, the University of Miami, and the University of Puerto Rico.

Observations were made from a twin engine Navajo aircraft carrying the Ames Airborne Tracking Sunphotometer and hyperspectral flux radiometers, an ASD spectrometer, and PCASP and FSSP particle probes. A well-equipped ground site contained a comprehensive array of in situ particle samplers, a transmissonmeter, narrow band and broad band radiometers and a lidar. Additional measurements were made offshore from University of Puerto Rico oceanographic research vessels and included both sunphotometer measurements of the aerosol and bio-optical observations of the sea water and chlorophyll concentration. The experiment was supported continuously by the NRL's dust transport and prediction model. Conditions during the experiment ranged from very clean to moderate dust loading. The heavy dust events noted in Puerto Rico in early June did not re-appear during the deployment. However, PRIDE is the first attempt of a comprehensive Saharan dust aerosol field experiment on the west side of the Atlantic and will provide new knowledge of aerosol characteristics and help validate MODIS retrieval algorithms.

10. Software development for deriving statistics from MODIS and AERONET aerosol properties

Software of MODIS Aerosol Products Subset Statistics (MAPSS) to subset MODIS and AERONET aerosol products is completed. The purpose is to create spreadsheet like files for validation. In detail, a box of 30 x 30 km^2 (or 50 x 50 km^2) is used to calculate statistics of aerosol optical depth, Angstrom coefficient, effective radius, and other related parameters from MODIS aerosol products. Similar files are also produced to include AERONET statistics within ±30 minutes of MODIS overpasses. The statistics include mean, standard deviation, maximum, minimum, and parameters from linear regression. Because of huge volume of MODIS data, the subset files are extremely useful for data analysis and archival. The software is executed automatically daily.

11. Development of aerosol assimilation model

Aerosol assimilation model is under development via fitting satellite and ground-based aerosol remote sensing data based upon a core of aerosol transport model developed by Dr. P. Ginoux. It is expected that this fitting procedure will improve model prediction by means of correcting aerosol sources being assumed in the model. The reprogramming of the model include the following physical mechanisms

- Aerosol diffusion due to air instability in planetary boundary layer
- Cloud convection

- Dry deposition of aerosol caused by diffusion air motion in air layer near surface
- Aerosol gravitational settling
- Wet removal of aerosol
- Three dimensional aerosol advection

Additional work is being done to enhance the flexibility of aerosol transport model in studying different scale scenarios by either decreasing or increasing the latitudinal, longitudinal, and vertical resolutions.

12   Analysis of measurements and calibration issue of ASD spectrometer

The calibration test of ASD against integrating sphere and gas lamp reveals serious problems. The spectral line error reaches as much as 20 nm, which is far greater than the acceptable range for detecting the spectral variation of various surfaces (e.g., vegetation, snow). After the replacement of a bad detector and replacement of some electronic parts, its calibration seems to reach a satisfactory level. Previously acquired data may be affected by bad calibration.

13.   Study of sub-pixel snow/ice using 0.66 and 2.1 μm channels

A carefully mapped TM snow scene was analyzed to develop and test the algorithm. The relationship between 0.66 and 2.1 mm is used to identify snow pixels and distinguish them from vegetation. The algorithm is expected to be able to detect sub-pixel snow of several percents. In the process we discovered that MODIS snow algorithm is insensitive to snow contamination when trying to identify snow free pixels. 13-day continuous measurements of snow between different phases are acquired using ASD spectrometer. Sub-pixel snow contamination results in uncertainties in the estimation of surface reflectance and subsequently the retrieval of aerosol optical depth.

14.   Revision of MODIS Atmosphere QA Plan

The MODIS Atmosphere QA Plan is revised to include changes of QA flags from MOD06 clouds products. The decision tree to identify cloud type is not properly coded in the algorithm. Other changes include post-processing QA procedures, including visualization software, statistical analysis report (i.e., time series, histogram), ancillary data (GOES, AVHRR, MISR, POLDER, OCTS, TOMS, etc.), and finally the update of science QA flag. The QA network systems include GDAAC, MODAPS, and Windhoek (MODIS atmosphere computing facility).

15.   Application of the MODIS aerosol, water vapor, and cloud mask algorithms to all SCAR-B and TARFOX MAS data

The analysis of SCAR-B and TARFOX MAS data using MODIS aerosol, water vapor and cloud mask algorithms are finished. Consistent statistics are derived in SCAR-B MAS data that smoke aerosol and water vapor show virtually no correlation in both forest and cerrado region, regardless of higher aerosol optical depth retrieved in the forest than that in the cerrado. In TARFOX, the MAS-derived optical thickness is much lower compared to that in SCAR-B but with the accuracy better than expected. Sun glint contamination is still a problem to be solved. This effort is to fully evaluate the MODIS aerosol algorithms over land and ocean.

16. Analysis of synoptic wind field using NCEP wind data for aerosol transport study

Different altitude winds of NCEP analysis data are used to analyze aerosol transport in western Africa and India subcontinent - the dust outbreak in Saharan desert and man made pollution. During the months of March and April, prevail winds carry strong dust storm westward to as far as South America and Caribbean regions. It could sometimes reach Bahamas and Florida. Trajectory analysis will be conducted to analyze the origin of the aerosols. In some scenarios, different aerosols are found in different altitudes. For example in Alexandria, Egypt, high aerosol optical thickness (>0.5) are found due to Kamaseen dust storms originated in Spring (March-April) in Sahara desert and low aerosol optical (<0.06) thickness are found due to air pollution in Western Europe. As a result of the back trajectory analysis, altitude dependence is found in terms of aerosol types (dust, sulfate, and mixed).

17. Analysis of the SeaWifs measurements during EOPACE-Duck Field Experiment

Five SeaWifs images are selected to be clear enough for consideration of deriving chlorophyll and aerosol data. The SeaWifs-derived aerosol optical depths are compared with those using MODIS aerosol ocean algorithm. In summary, 3 out of 5 cases using MODIS algorithm are found in good agreement with aerosol optical depths measured by Sun photometer at **0.865** μm. The reason is not known. Since the MODIS and SeaWifs orbits have only 1 hour difference in overpass time, we plan to use MODIS measurements together with SeaWifs measurements in the future to unwrap this issue.

18. Paper acceptance/submission/preparation

Kaufman, Y. J., A. Karnieli and D. Tanré, Detection of dust over the desert by EOS-MODIS. *IEEE TGARS accepted.*

Kaufman, Y. J., D. Tanré, O. Dubovik, A. Karnieli, and L.A. Remer, 1998: Satellite and Ground-based Radiometers Reveal Much Lower Dust Absorption of Sunlight than Used

in Climate Models, submitted to Nature and in renegotiations stage Jan 2000

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Kleidman, R. G., Yoram J. Kaufman, Lorraine A. Remer, Richard A. Ferrare and Bo-Cai Gao , Remote Sensing Of Total Precipitable Water Vapor In The Near-IR Over Ocean Glint, accepted to GRL.

Li, Z., Y. J. Kaufman, C. Ichoku, R. Fraser, A. Trishchenko, L. Giglio, J. Jin, 2000, A review of satellite fire detection algorithms: Principles, limitations, and recommendations, *Rem. Sens. Environ*., A special issue on GOFC-FIRE, Submitted.

Remer, L.A., A.E. Wald, Y.J.Kaufman, Angular and seasonal variation of surface reflectance ratios: Application to the remote sensing of aerosol over land. *IEEE Transactions on Geoscience and Remote Sensing*, accepted.

Sabbah I., Charles Ichoku, Yoram Kaufman, and Lorraine Remer, Climatology of desert dust spectral optical thickness and precipitable water vapor over Egypt in 1998, accepted to JGR.

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Chu, D. A., Y. J. Kaufman, D. Tanré, B. N. Holben, R. R. Li, Smoke optical properties derived from airborne measurements in Brazil, in preparation to submit to JGR.

19. Conference/workshop

American Geophysical Union Spring Meeting, Washington DC, May 30 - June 3, 2000. (*Kaufman, Remer, Chu)*

MODIS Atmosphere Group meeting, Goddard Space Flight Center, Greenbelt, November 14, 2000. (*Kaufman, Remer, Chu, Mattoo, Li, Levy, Ichoku*)